



During the period of March 20 - 31, 1967, in Miami, Florida, Milgo Electronic Corporation held a series of one-day demonstrations of narrow-band data modems. Digital data was transmitted over an unconditioned 3000 mile telephone line at rates of 2400 bps and 4800 bps, using Milgo data sets MODEM 4400/24 and MODEM 4400/48.

The following is a synopsis of the demonstrations.

Introductory Remarks

Jack B. Gerber, Marketing Manager - Data Communication Products, discussed Milgo's 12-year history in the field of data transmission and handling, leading to development of the narrow-band concept of data transmission announced last November. Mr. Gerber described Milgo's six product areas: Data Communications; Data Handling Systems; Data Display Systems; Analog Computers; Newspaper Production Control Systems; and Business Equipment. He discussed the firm's \$6.5 million annual production of quality electronic instrumentation, and conducted a tour through the 100,000 square foot Milgo plant.

Mr. Sang Youn Whang, Technical Specialist who developed Milgo's narrow-band concept of transmission, discussed design goals, and history of accomplishment in narrow-band data transmission, including some of its more valuable applications. He described the advantages inherent in transmitting over only the best portion of a transmission channel, avoiding the areas of severe line distortion. The significant benefits, not available in other data sets, include (1) elimination of the need for conditioned lines, (2) substantial reduction of susceptibility to impulse noise, and (3) release of the unused bandwidth for other purposes such as simultaneous Teletype transmission.

The promise of these advantages encouraged Milgo management to investigate the development of this concept into a product. Six months after the decision to proceed, Milgo produced a working prototype of a 2400 bps data modem utilizing 800 cycles of bandwidth. Six months later, Milgo received a two-year contract from Western Union for MODEM 4400/24, with an initial delivery exceeding \$600,000.

Operational Demonstration of MODEM 4400/24 and MODEM 4400/48

The demonstration was made over an unconditioned Schedule 4 line, leased from the Bell System and looped back to Miami (see Figure 1). Demonstrations consisted of (A) Observation of received spectrum on spectrum analyzer; (B) Observation of simultaneous data transmitted with the 2400 bps on the same line; (C) Long term error run of 2400 bps equipment set up as in (B) and of 4800 bps unit. Details of these demonstrations are described below.

A. Observation of received spectrum —

One MODEM 4400/24 was connected to the line using its transmit side on the outgoing pair and its receiver on the return pair. A Panoramic LP-1a spectrum analyzer showed a received spectrum of 1300 Hz to 2100 Hz with very steep sides and no additional transmitted energy in any other part of the band. A MODEM 4400/48 was then attached in a similar fashion and the spectrum observed to be 900 Hz to 2500 Hz with no additional transmitted energy elsewhere in the band.

B. Observation of simultaneous data —

The MODEM 4400/24 was attached to the line as in (A) and a 100 wpm, 75 baud, Model 28 Teletype, transmitting by means of a Western Union type 65 terminal unit, was attached to the summing amplifier of the modem (see Block Diagram CPD6897). The terminal unit had a center frequency of 525 Hz. To occupy the remaining bandwidth and simulate additional Teletype channels, five audio oscillators, H-P 200CD, were summed into the line. The frequencies were 800 Hz, 1000 Hz, 2400 Hz, 2700 Hz, and 3000 Hz. All signals put on the line were received back at equal amplitude within 1 db. The aggregate signal was transmitted at -8 dbm. A spectrum analyzer, Panoramic LP-1A, was connected to the line to indicate the presence and location of the various signals. It was verified that the main data signal was only between 1300 Hz and 2100 Hz, an 800 Hz bandwidth, and that the other signals were present at the received end of the line in their proper location. The input to the modem keyer was connected to a standard 16-bit, switch settable, pattern generator. The demodulated received signal was entered, along with the generated pattern, into an error detector. Errors were counted by the binary lights on the front panel of the error detector.

Error rates better than 1 in 10^6 were consistently observed.

C. Long Term Runs -

2400 bps

At a 2400 bps rate, slightly over 1×10^6 bits are transmitted every seven minutes. Therefore, most sustained runs at 2400 bps were for seven or fourteen minutes and error rates better than 1 in 10^6 were consistently observed. Occasionally, error rates somewhat worse than this were observed due to line dropout. These occurred, as expected, in groups, usually 3 to 10 bits at one time. No long term run revealed error rates worse than 1 in 10^5 . The longest term run was for 56 minutes (8 million bits), during the noisiest time of day, 12:00 Noon to 12:56 PM, on 30 March. This run produced 1 error; i.e., a rate of 0.124 in 10^6 . The 56 minute test was accomplished with all equipment operating simultaneously as described in (B) above. Not all the other tests were run simultaneously with TTY, but no difference was observed in error rates due to the presence or absence of TTY signals. In each of the cases discussed, the written TTY output was examined and no errors were observed.

4800 bps

The production units of the 4400/48 will include a very easily operated, self-contained, variable equalization circuit to permit operation over unconditioned, leased lines of the Schedule 4 type. The unit available during this demonstration was not equipped with this feature, so a Milgo eight-pole variable data line equalizer was substituted externally. After setting this equalizer to the optimum condition, several significant changes were made temporarily to the settings to demonstrate the MODEM 4400/48 tolerance to different line conditions. It was observed that changes at individual poles of 300 μ sec made no difference in error rate.

At 4800 bps, slightly over 1×10^6 bits are transmitted every 3 - 5 minutes. Numerous test runs, at various times of day, yielded error rates consistently better than 1 in 10^6 . However, line dropout did upon occasion deteriorate this error rate to between 1 and 10 in 10^6 . Since the rate of transmission was twice as fast as 2400, about twice the number of bits were observed in each burst of errors.

Additional Information

A number of questions were raised during the demonstration regarding certain features of MODEM 4400. Many of these related to specific application and are not related here. However, some of the general features of interest to most users are summarized below:

1. Limited spectrum requirements — The Milgo 4400 series modems require one cycle of bandwidth per 3 bps of transmission. MODEM 4400/24 requires only 800 Hz of bandwidth for a transmission rate of 2400 bps. Similarly, MODEM 4400/48 requires only 1600 Hz to transmit 4800 bps. With MODEM 4400/24, this limited bandwidth allows the user to take advantage of the inherent characteristics of 3 kc voice channels without special conditioning. The primary concern is envelope delay and amplitude distortion. Typical delay characteristics obtained by extensive measurement of Bell System phone lines* throughout the U.S. were studied and it was noted that by selecting the bandwidth between 1300 Hz and 2100 Hz we avoid the areas of substantial envelope delay variation. Further, by constructing a compromise equalizer, such as that provided in MODEM 4400/24, we can tolerate and operate over any of the leased lines likely to be encountered.

In the case of MODEM 4400/48, 1600 cycles of bandwidth is required, necessitating variable equalizers to meet various line conditions. Note, however, that this is approximately the bandwidth required by other manufacturers' 2400 bps modems. Milgo transmits 4800 bps data in this bandwidth, minimizing the problems to the point that only about 5 sections of equalization are required to operate over an otherwise unconditioned line, such as Schedule 4.

* As described in The Bell System Technical Journal, Vol. XXXIX, No. 3, pp. 431 - 476, May 1960.

2. High noise immunity — In the presence of white noise, band limited to the transmission spectrum, MODEM 4400/24 will operate, back to back, with less than one error per million at a signal to noise ratio of about 20 db. Similarly, MODEM 4400/48 will operate at this error rate with a signal to noise ratio of about 23 db, back to back. In the presence of high impulse noise on the signal lines, MODEM 4400 offers substantially more protection than is possible by other techniques. This is accomplished by the inherent characteristics of narrow-band filters, as well as by smearing/de-smearing techniques employed in the transmitter and receiver.
3. Power and radiation protection — Power transients and local noise susceptibility is greatly reduced by use of an instrument type shielded transformer (with capacitive coupling of less than 1 pico farad) and other shielding techniques.
4. No operational adjustment or tuning — There is absolutely nothing to adjust or tune in MODEM 4400/24 after installation. Even MODEM 4400/48 will reduce the usually complex task of initial equalization to a simple matter of nulling a meter.
5. High reliability — The only switch used is for test mode; potentiometers are not used at all in MODEM 4400/24 and are only in the equalizer portion of MODEM 4400/48. Extensive use of integrated circuits together with silicon devices insures reliability in extreme environments.
6. Complete compatibility — A flexible interface including, if desired, complete RS232B, assures ability to match user requirements.
7. Wide range AGC — Dynamic range of 36 db with response of 100 db/sec. may be set for any nominal level, bracketed by +5 to -55 dbm.
8. Fast response carrier detection — Only 50 milliseconds is required after "Request to Send" for "Clear to Send" response and the receipt of data. This is especially valuable in polling and other applications where carrier is frequently turned off and on or shifted from one transmitter to another.

3000 MILE SCHEDULE 4 LINE (looped)

March 15, 1967

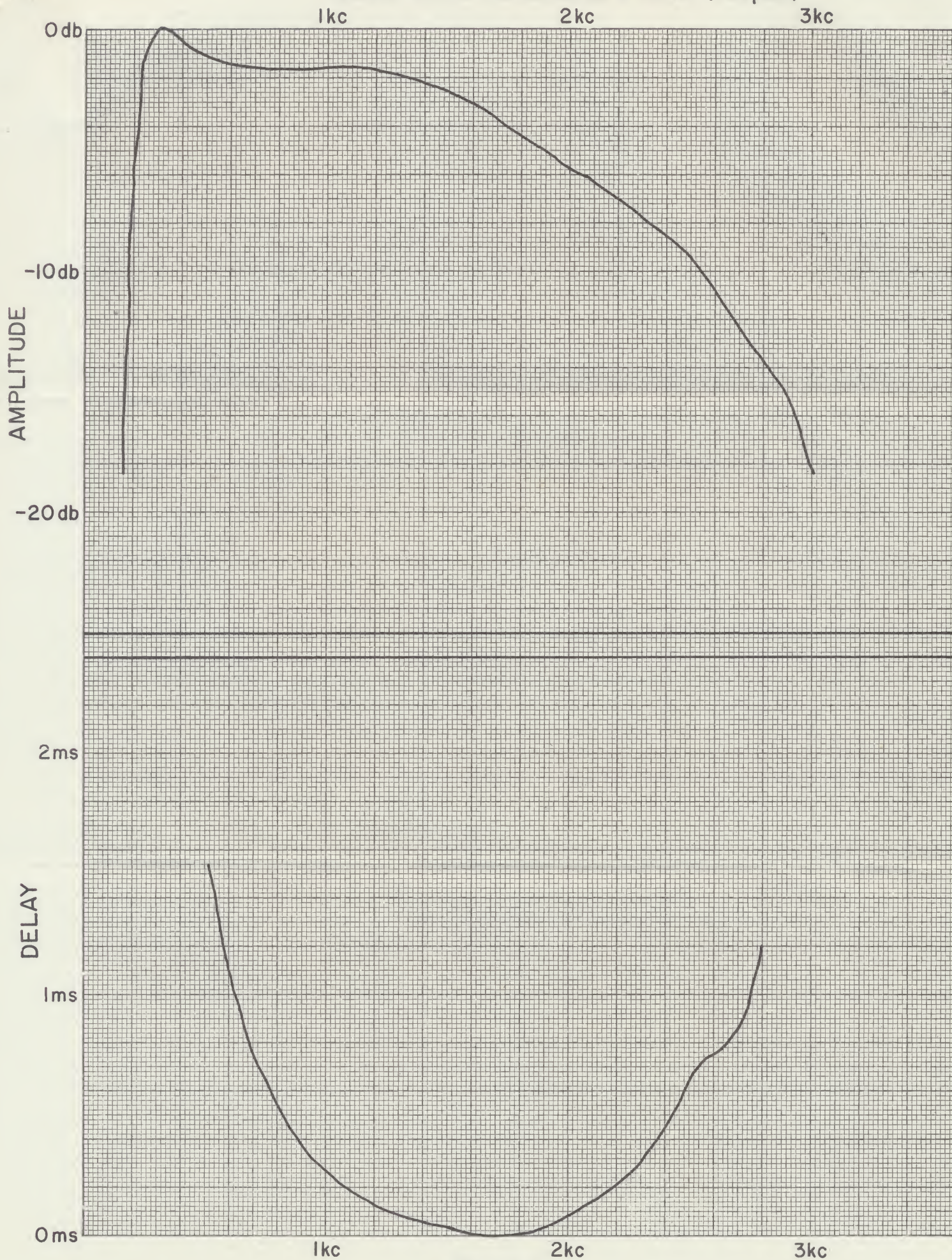


Figure 1

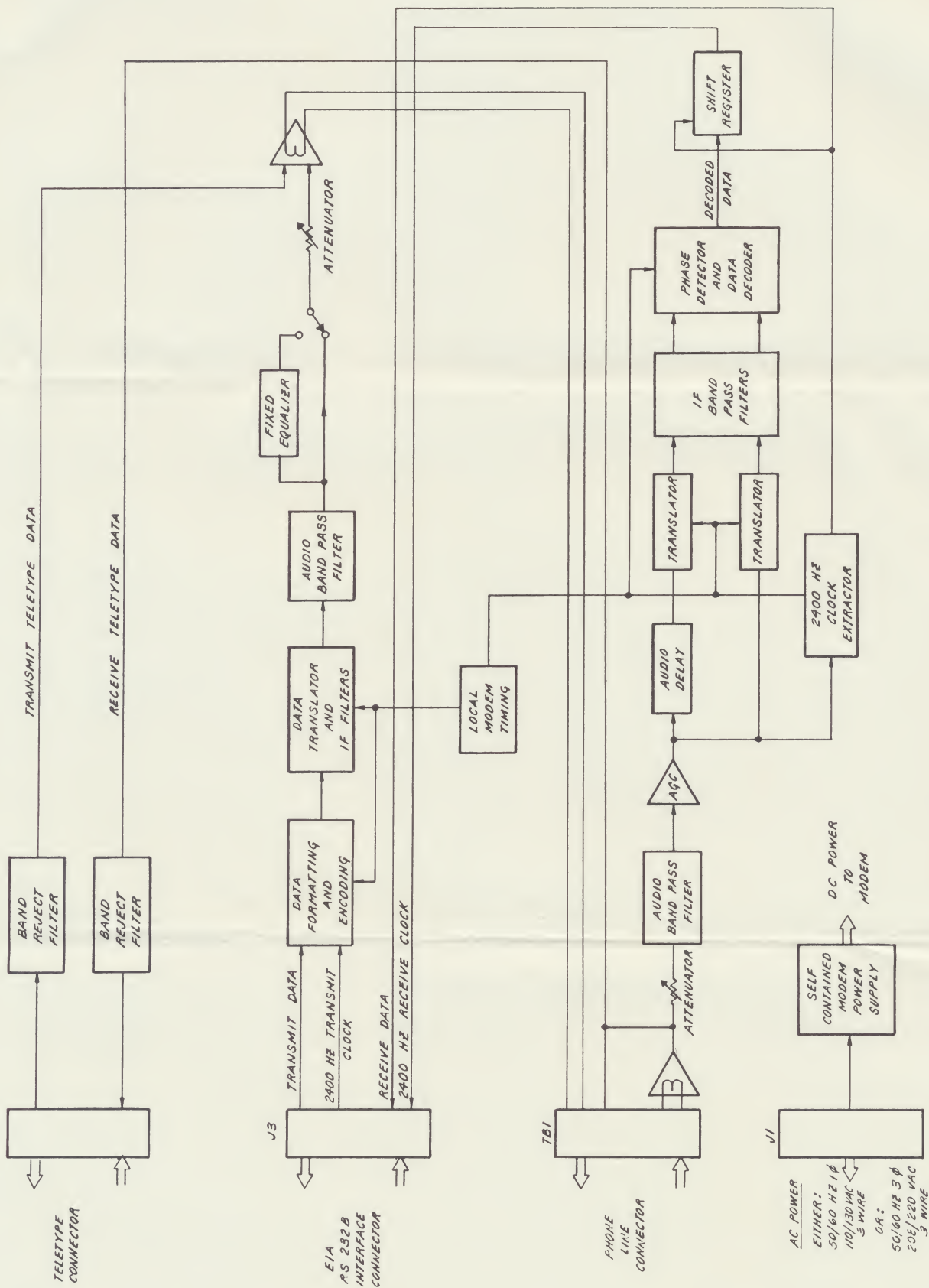


Figure 2. 2400 bps Data Modem, Block Diagram (CPD6897/0)